CHAPTER 9 RESERVOIR DESIGN AND STORAGE VOLUME

In accordance with engineering standards of care, reservoirs are to be designed to provide stability and durability, as well as protect the quality of the stored water. For any particular project there may be more than one acceptable reservoir design concept. The reservoir design criteria are not intended to establish any particular design approach, but rather to ensure water system adequacy, reliability, and compatibility with existing and future facilities.

9.0 Storage Volume Components

For a given reservoir design, each of the five (5) storage component listed below, as discussed in Section 6.7.3, **must** be considered [WAC 246-290-235(3)]:

1. Operational storage (OS);
2. Equalizing storage (ES);
3. Standby storage (SB);
4. Fire suppression storage (FSS); and
5. Dead storage (DS), if any.

Figure 9-1 illustrates, and Table 9-1 describes, a typical cross-section of the reservoir storage components. Section 9.0.5 provides the basis for determining when the smaller of the SB or FSS components may be deleted from the total storage volume. Section 9.1.3 provides guidance for reduction or elimination of the storage volumes as defined below. Only ***effective storage***, as defined in Section 9.0.1, may be used in determining the actual available, or design, storage volume.

9.0.1 Effective Storage

Total tank volume, as measured between the overflow and the tank outlet elevations, may not necessarily equal the effective volume available to the water system. Effective volume is equal to the total volume less any ***dead storage*** built into the reservoir. For example, a standpipe has a component of its capacity which is intentionally designed as dead storage, meaning that below a certain water surface elevation within the tank, the pressure delivered to (some) customers falls below minimum pressure requirements for the system.

Conversely, if a water system's source (well or booster pump) is not capable of delivering a design rate of flow above a certain water surface elevation within the tank, then this upper volume of the tank is considered unavailable to the system and is not a part of the effective storage.

The amount of effective storage may also be dependent upon the location of the storage relative to the place of its use (whether or not it is in a different pressure zone and what distance the water needs to be conveyed).

9.0.2 Operational Storage (OS)

Consistent with the definition presented in WAC 246-290-010, operational storage is the volume of the reservoir devoted to supplying the water system while, under normal operating conditions, the source(s) of supply are in “off” status. This volume will vary according to two main factors: (1) the sensitivity of the water level sensors controlling the source pumps, and (2) the configuration of the tank designed to provide the volume required to prevent excessive cycling (starting and stopping) of the pump motor(s). The definition specifies that OS is an additive quantity to the other components of storage. This provides an additional factor of safety to the ES, SB, and FSS components if the reservoir is full when that component of storage would be needed.

Water level sensors may vary from mercury-type float switches to ultrasonic sensors to pressure switches. Each type has a different sensitivity to water level changes from fractions of inches to more than a foot. The tank designer will have to account for the type of level sensor specified when determining the vertical dimension needed for proper operation of the device. Manufacturer’s specifications generally govern the determination of this dimension.

Once the pump control device is selected, the tank designer will be able to factor in the vertical dimension when determining the other aspects of tank configuration, such as the width and height, as well as the shape. The volume of OS should be sufficient to avoid pump cycling in excess of the pump motor manufacturer's recommendation. Historically, a rule of thumb was to limit the motor to no more than six starts per hour. However, many manufacturers will warrant more frequent cycling for their pump motors, depending upon the size of the pump.

The OS volume determined in this situation is comparable to the withdrawal volume required when using hydropneumatic tanks for pump motor protection. “Ten States Standards” recommends that the gross volume of the hydropneumatic tank, in gallons, be at least ten times the capacity of the largest pump, rated in gallons per minute. Withdrawal volume of a hydropneumatic tank is usually on the order of 25% of the gross volume. Using this relationship, it would be recommended that the OS volume be about 2.5 times the capacity of the largest pump. Calculating the OS volume will verify that typically, for gravity storage tanks, it is substantially less than the remaining volume of the tank. The volume associated with the elevation difference required for the pump level sensors is usually larger than that required for pump motor protection, so that volume generally becomes the limiting factor when determining the OS volume required.

Operational storage does not apply to systems operating under a continuous pumping mode [see Section 9.0.3(1)]. Under this situation, pump motor protection is assured by the operational mode and the other components of effective storage (ES, SB, and FSS) are all that need to be considered.

9.0.3 Equalizing Storage (ES)

When the source pumping capacity cannot meet the periodic daily (or longer) peak demands placed on the water system, Equalizing Storage (ES) **must** be provided [WAC 246-290-235(2)] as a part of the total storage for the system and must be available at 30 psi to all service connections. The volume of ES depends upon several factors, including peak diurnal variations in system demand, source production capacity, and the mode of operation (either continuous pumping for a select period of time or by "call-on-demand" through use of reservoir level control switches). Each water system should be evaluated based on its mode of operation and hydraulic capabilities.

1. **Continuous Pumping**

   The method for determining ES requirements depends upon the mode of source pump operation. If pumping is to be continuous for a period of time sufficient to provide the total maximum day demand, it is necessary to prepare a mass analysis by either graphical or tabular methods, or a computer simulation. Varying system head curves and demand scenarios should be evaluated to determine the maximum ES volume required by the system.

2. **Call-On-Demand**

   Equation 9-1 shown below should be used for estimating minimum ES requirements, unless actual water use records indicate a more applicable volume. Water systems with multiple sources may need to provide ES in excess of Equation 9-1 depending upon the mode of operation. This may involve storing multiple days of volume to meet maximum system demands.

   Equation 9-1:

   $$ES = (PHD - Q_S)(150\ \text{min.})$$ *, but in no case less than zero.*

   Where: ***ES*** = *Equalizing storage component, in gallons.*

   PHD = *Peak hourly demand, in gpm, as defined in Chapter 5 of this manual.*

   Q_S = *Sum of all installed and active source of supply capacities, except emergency sources of supply, in gpm. (See Section 9.1.1 for the definition of source.)*

9.0.4 Standby Storage (SB)

The purpose of SB is to provide a measure of reliability should sources fail or when unusual conditions impose higher demands than anticipated. The SB volume recommended for systems served by one source may be different than for systems served by multiple sources as described in the following sections.

1. **Water Systems With A Single Source**

   The recommended SB volume for systems served by a single source of supply is two (2) times the system's *average day demand* (ADD) for the design year to be available to all service connections at 20 psi. ADD is defined in Chapter 5 of this manual.

   Equation 9-2:

   $$SB_{TSS} = (2\ \text{days})(ADD)(N)$$

   Where: SB_{TSS} = *Total standby storage component for a single source system, in gallons;*

   ADD = *Average day demand for the design year, in gpd/ERU; and*

   N = *Number of ERUs.*

2. **Water Systems With Multiple Sources**

   The recommended SB volume for systems served by multiple sources **should** be based upon the following equation:
   Equation 9-3:

   $$SB_{TMS} = (2\ \text{days})(ADD)(N) - t_m\ (Q_S - Q_L)$$

   Where: SB_{TMS} = *Total standby storage component for a multiple source system; in gallons*

   ADD = *Average day demand for the system, in gpd/ERU;*

   N = *Number of ERUs;*

   Q_S = *Sum of all installed and continuously available source of supply capacities, except emergency sources, in gpm. See Section 9.1.1 for the definition of a continuously available source.*

   Q_L = *The largest capacity source available to the system, in gpm.*

   t_m = *Time that remaining sources are pumped on the day when the largest source is not available, in minutes.(Unless restricted otherwise, this is generally assumed to be 1440 minutes.)*

Note: Although SB volumes are intended to satisfy the requirements imposed by system customers for unusual situations and are addressed in WAC 246-290-420, <u>it is recommended that the SB volume be not less than 200 gallons/ERU.</u>

3. **Standby Storage (SB) for Recreational and Non-Critical Commercial Uses**

   There is no recommendation for SB for systems made up entirely of the following non-community uses: (1) RV parks, (2) camp grounds, (3) fair grounds, (4) outdoor concert grounds, (5) restaurants, and (6) non-critical commercial uses. It is generally assumed that these systems could reasonably be shut down in the event of a loss of water supply without impacting public health and welfare. There is also no recommendation for SB for recreational-residential water systems (those systems used predominantly for recreational purposes that do not permit through covenant or other means, nor do they currently have, *any* permanently fixed-in-place residential structures.)

   Schools, hospitals, and recreational-residential water systems serving permanent fixed-in-place residential structures are examples of non-community systems for which the SB recommendation applies.

4. **Standby Storage (SB) for Non-Community Uses**

   SB for non-transitory non-community water systems with a single source should be the same as defined in Section 9.0.4(1). SB for non-transitory non-community water systems with multiple sources should be the same as defined in Section 9.0.4(2). Non-community water demands **must** be determined as defined in WAC 246-290-221(2). Chapter 5 of this manual presents some recommended criteria that apply to non-community water uses.

5. **Reduction in Standby Storage**

   The purveyor and system designer have a number of options available to decrease the volume of SB in the system. As indicated in item 2 (above), the volume may be reduced with development of additional sources of supply. To be considered equivalent to gravity storage, the sources would also need to be equipped with auxiliary power that starts automatically when the primary power feed is disrupted. The purveyor may also reduce the volume if community expectations are amenable to a lesser SB capacity, such as their agreeing that the volume for one average day of service would be sufficient for standby purposes instead of two days. A utility may also make better use of dead storage by providing booster pumps at the point where the pressure reaches the minimum established by the community in situations when the SB is used.

9.0.5 Fire Suppression Storage (FSS)

Public water systems are **required** to construct and maintain facilities, including storage reservoirs, capable of delivering fire flows in accordance with the *determination of fire flow requirement* made by the local fire protection authority or County Fire Marshal while maintaining 20 psi pressure throughout the distribution system [WAC 246-290-221(5)]. The magnitude of FSS is the product of the maximum flow *rate* and *duration* established by the local fire protection authority or County Fire Marshal. For water systems located in areas governed under the Public Water System Coordination Act of 1977 (PWSCA), Chapter 70.116 RCW, minimum flow rates and durations that **must** apply for residential, commercial, and industrial developments are specified in the Water System Coordination Act regulations, WAC 246-293-640. Greater FSS requirements may be specified by the local fire protection authority, County Fire Marshal, and/or locally adopted Coordinated Water System Plan.

Minimum FSS Volume

The minimum FSS volume for systems served by a single source of supply or multiple sources of supply is the product of the required flow rate (expressed in gpm) multiplied by the flow duration (expressed in minutes).

Equation 9-4:

$$FSS = (FF)(t_m)$$

Where: FF = *Required fire flow rate, expressed in gpm, as specified by fire protection authority or the Coordination Act, whichever is greater; and*

t_m = *Duration of FF rate, expressed in minutes, as specified by fire protection authority or the Coordination Act, whichever is greater.*

Special Note: SB and FSS Consolidation (Nesting)

The SB component or the FSS component, whichever volume is smaller, can be excluded from a water system's total storage requirement provided that such practice is not prohibited by: (1) a locally developed and adopted Coordinated Water System Plan, (2) local ordinance, or (3) the local fire protection authority or County Fire Marshal. [See WAC 246-290-235(4)]

9.0.6 Dead Storage (DS)

Dead storage (effective only to provide adequate pressure) is the volume of stored water not available to all consumers at the minimum design pressure in accordance with WAC 246-290-230(5) and (6). DS volume is excluded from the volumes provided to meet OS, ES, and/or FSS requirements. Local community standards apply as to whether or not some DS volume may be used to provide SB volume to meet minimal community expectations during unusual operating conditions.

9.0.7 Storage Used for Treatment Purposes

Sometimes, storage volume is needed to provide adequate contact time for routine disinfection practices or to meet surface water treatment requirements (See SWTR Guidance Manual.) When storage volume is provided to meet a water treatment requirement, the designer will be required to determine the volume necessary. They will also need to describe how the reservoir design and configuration will provide adequate treatment and public health protection under all reasonably anticipated operating conditions. The FSS and/or SB volume should not be considered as part of this volume, and the designer should clearly articulate to the system owner that the risk to public health will increase if or when the storage volume is decreased and eventually depleted. It is also important to understand that a Treatment Technique Violation can occur whenever insufficient storage is available to provide the disinfectant contact time required. The owner and/or community may desire to increase the storage volumes provided to reduce that risk. ***DOH recommends that storage volume required to meet surface water treatment requirements be separate from the distribution storage provided.***

9.1 Reservoir Sizing Considerations

All storage volumes may be reduced if source water is reliably available to meet all demands at the required flow rate and duration. Following are some elements to evaluate when considering reductions for the designed storage volumes.

9.1.1 Definition of Source as Used in Sizing New Reservoirs

Any source classified as either permanent or seasonal may be considered a source for the purpose of designing new reservoir facilities provided that the source is ***continuously available*** to the system and at a minimum meets all primary drinking water standards [WAC 246-290-010, -222(3), and -420(2) & (5)]. To be continuously available to the system means that: (1) the source is equipped with functional pumping equipment (and treatment equipment if required); (2) the equipment is exercised regularly to assure its integrity; (3) water is available from the source year round; and (4) the source is activated automatically based on pre-set parameters (reservoir level, system pressure, etc.)

For the purpose of designing new reservoir facilities, the following are considered sources:

1. Each pump in a booster pump station (pumps installed in parallel, not series) pumping into the zone served by that particular reservoir.
2. Each independent, parallel treatment train in a water treatment facility.

3. Each well, or well field comprised of wells, constructed per Chapter 173-160 WAC, Minimum Standards for Construction and Maintenance of Wells, and capable of pumping concurrently as justified by actual pump test records.
4. Each pump installed in a large capacity, large diameter well provided that each pump can be taken out of service without the need to interrupt operation of any other pump.
5. An emergency intertie, provided that: (1) the intertie is equipped with an automatic valve; (2) the intertie agreement specifically includes provision of SB and/or FSS; and (3) the intertie, supplying, and receiving distribution systems have sufficient hydraulic capacity to deliver the allocated flow at no less than the minimum pressure required by WAC 246-290-230. If the intertie requires booster-pumping facilities, then each pump installed in parallel constitutes a source.
6. A pressure reducing valve between pressure zones within the same system provided that: (1) adequate volume is available in the upper zone's storage facilities; and (2) the distribution system (from the upper zone through the PRV to the end use in the lower zone) has sufficient hydraulic capacity to deliver the allocated flows, whether they are to meet or augment peak hour flows or fireflows, at no less than the minimum pressure required by WAC 246-290-230.

The actual installed capacity of the facilities and equipment is to be used when determining service capacity based on storage requirements for existing systems.

9.1.2 Storage for Consecutive Systems

A consecutive water system (those systems which purchase all of their water supply from another regulated water system), may utilize the storage available from the supplying system to satisfy the requirements of Chapter 9, provided that:

1. The wholesale water agreement between the supplying system and the consecutive system defines the quantity of ES, SB, and FSS operated by the supplying system that is specifically reserved for the consecutive system; and
2. It can be demonstrated that both the supplying and consecutive system can satisfy the hydraulic design criteria described in Sections 8.2.3 and 9.3.

9.1.3 Alternate Design Concept

The ES and SB components summarized in Section 9.0 may be reduced or, in some instances, eliminated provided that the water system design includes multiple sources of supply and in some cases on-site standby power. ES may be eliminated only if the combined capacity of the sources of supply meets or exceeds the PHD for the system, and/or the pressure zone, with 30 psi pressure provided at each existing and proposed service connection. The FSS component of storage design may be reduced or, in some cases eliminated, provided the water system design includes on-site standby power and the system is served by multiple sources of supply that are capable of providing the fireflow rate in addition to the MDD rate for the system. This should be verified with the local fire protection authority.

Water systems substituting source capacity for storage volumes need to consider and provide appropriate justification for varying from the following criteria:

1. Exclude the capacity of the largest producing source of supply from the calculations;
2. Each source of supply used in the calculations be equipped with on-site back-up power facilities, promptly started by an automatic transfer switch upon loss of utility power.
3. Incorporate provisions for pump protection during low demand periods into the system design.

9.1.4 Design Life

Storage facilities are normally designed to serve the needs of the community for a planned number of years, or to accommodate full system build-out (if they serve a particular subdivision or planned development, or fulfill a condition of plat approval, etc.) The design life for properly maintained concrete and steel storage tanks is typically assumed to be about fifty years. Any other type of storage tank that does not have the historical longevity of these tanks needs to be evaluated on a life cycle cost basis before being considered for use.

9.2 Establishing Overflow Elevations

Considerations for establishing overflow elevations for reservoirs designed to provide gravity water service include:

1. **Consistency With Other Facilities and Plans**

   The overflow elevation should be consistent with other storage facilities in use or planned by the water system. Overflow elevation of existing or proposed facilities of other nearby water systems should also be considered.

2. **Consistency With Pressure Requirements and Limits**

   The tank overflow elevation should be consistent with pressure requirements and pressure limitations within the existing and future water service area. The designer should consult topographic maps in addition to information received from the system hydraulic analysis described in Section 8.2.

3. **Consistency With Source Capacity**

   Tank elevation and tank geometry should be coordinated with source equipment discharge-head characteristics to assure that source capacity requirements established by DOH are met. Pump curves should be developed and detailed hydraulic analyses prepared of existing and future distribution system conditions (pipe network and water demand).

4. **Maintaining Levels**

   To assure levels are maintained in reservoirs throughout the system, use altitude valves where appropriate.

9.3 System Pressure Considerations

The hydraulic design criteria for new and existing water systems is described in this section. Figure 9-1 provides a graphic view of the reservoir hydraulic design criteria described below. Chapter 5 of this manual defines peak demand periods, including the maximum day demand (MDD) and peak hourly demand (PHD).

9.3.1 Fire Suppression Storage (FSS) Component

For systems supplied through gravity storage, the bottom of the FSS component **must** be located at an elevation which produces no less than 20 psi at all points throughout the distribution system under the flow conditions (MDD rate plus fireflow) described in WAC 246-290-230(6). Where some of the fireflows are supplied by pumping, it is recommended that the analysis be completed assuming that the largest source is out of service. This assumption and analysis **is required** where section 660 of the Water System Coordination Act, Chapter 246-293 WAC, applies.

Any one or combination of design parameters including the tank elevation, tank geometry, tank location, and/or the distribution piping network may be modified to meet the 20 psi residual pressure standard. The design engineer is responsible for providing evidence of a hydraulic analysis, as per Section 8.2 of this manual.

9.3.2 Standby Storage (SB) Component

The lower elevation of the SB component should be that which produces no less than 20 psi at all existing and proposed service connections throughout the distribution system under PHD conditions, assuming that the largest source is not in service.

Any one or combination of design parameters including the tank elevation, tank geometry, tank location, and/or the piping network may be modified to meet the 20 psi residual pressure. The design engineer is responsible for providing evidence of a hydraulic analysis, as per Section 8.2 of this manual.

9.3.3 Consolidation (Nesting) of Standby (SB) and Fire Suppression Storage (FSS)

If consolidation of SB and FSS is proposed, as allowed per WAC 246-290-235(4), the evaluation of storage volume elevation must be completed per Section 9.3.1 above. The evaluation at higher elevations or pressures would only be necessary if the local community establishes a higher level of service for conditions under which standby storage is used.

9.4 Site Feasibility Considerations

Site feasibility considerations should include:

1. Sufficient area to construct and maintain the facility, as well as allow room to site additional storage to meet projected growth.
2. Distance to the existing distribution and transmission system.
3. Need for new distribution and transmission pipelines to meet pressure standards.
4. Existing ground surface elevation and site drainage.
5. Site access, anticipating potential seasonal limitations.
6. Geotechnical engineering field investigations including:
    a. foundation design requirements,
    b. soil type/soil bearing strength, and
    c. ground water table elevation.
7. Availability of power.

9.5 Special Design Considerations Based on Type of Reservoir

Special design considerations for reservoirs and storage tanks should include:

9.5.1 Back-up Power Recommendations For Non-Elevated Reservoirs

DOH recommends that systems relying on non-elevated reservoirs (i.e., reservoirs that can only supply a distribution system in whole or in part through a booster pump station) be equipped with onsite back-up power facilities or, at least, with the ability to readily connect to a portable generator. (Booster pump design guidelines are described in Chapter 10 of this manual.) It is also recommended that the back-up power facilities be designed to start, through an automatic transfer switch, upon interruption of the utility power supply. *Manual transfer may be sufficient providing it can be done within a reasonable time period in accordance with established* *operating procedures*. The primary intent for recommending back-up power is to assure that the system is pressurized at all times to minimize cross-connection contamination concerns.

9.5.2 Ground Level and Underground Reservoirs

The following recommendations apply to ground level, partially buried and underground reservoirs:

1. Ground level, partially buried and underground reservoirs should be placed outside the 100-year flood plain.
2. The area surrounding a ground level or below grade reservoir should be graded in such a manner that will prevent surface water from standing within 50 feet of the structure, at a minimum.
3. When the reservoir bottom is below normal ground surface, it should be placed above the groundwater table, if possible. If this is not possible, special design considerations should include providing perimeter foundation drains to daylight and exterior tank sealants. These are necessary to keep ground water from entering the tank and to protect the reservoir from potential flotation forces when the tank is empty.
4. Partially buried or underground reservoirs should be located at least 50 feet from sanitary sewers, drains, standing water, and similar sources of possible contamination. Pipe typically used for water mains should also be used for gravity sewers if they are located within 50 feet of the reservoir. These pipelines should be pressure tested in place to 50 psi without leakage.
5. The top of the reservoir should not be less than two feet above normal ground surface, unless special design considerations have been made to address maintenance issues and protection from surface contamination.

9.5.3 Tank Materials in Contact with Potable Water

All additives, coatings, and compounds proposed for use in substantial contact with potable water, such as those listed below, **must** have ANSI/NSF certification per WAC 246-290-220 for contact with potable water. These materials also need to be carefully applied in accordance to the manufacturer's recommendations for that particular material. To avoid unnecessary public health concerns and consumer complaints regarding aesthetic qualities, the design engineer should address the following concerns:

1. For concrete tanks, use appropriate form oils, concrete surface sealants, and curing compounds or plasticizers.

2. For steel tanks, consider the materials used to prepare the surface of the tank, as well as the painting or coating systems used to protect against corrosion. Cathodic protection should be provided as necessary (especially for underground or partially buried tank installations).

3. Reservoirs employing membrane liners, plastic tanks, or other alternate designs should be ANSI/NSF certified.

4. Temperature, time, and ventilation conditions, as well as the thickness of the applied layers, specified for proper curing of coatings are critical elements to assure protection against the leaching of undesirable levels of substances into the water. In circumstances where there is any concern over the curing of the coatings and materials applied, or over the leachability of the reservoir liner, DOH may require additional water quality monitoring on water drawn from the reservoir prior to the reservoir being placed into service. ***Refer to Appendix H for additional guidance regarding leachable materials testing.***

9.6 Reservoir Appurtenant Design

All reservoir appurtenances should be designed to be water tight and **must** [WAC 246-290-235(1)] have means to prevent entry by birds, animals, insects, excessive dust, and other potential sources of external contamination, including cross-connections. All reservoir appurtenances should be designed to protect against freezing and ice damage which will interfere with proper functioning, (such as tank level controls, riser pipes, overflows, and atmospheric vents).

9.6.1 General

The following elements should be considered as part of the overall reservoir appurtenances design:

1. Installed reservoir isolation valve(s), which permit isolating the tank from the water system. [A provision for tank isolation is required per WAC 246-290-235(1)].
2. Installed air release/vacuum release valve on the distribution system side of the isolation valve.
3. Installed sample tap on the tank side of the isolation valve. [A provision for sample collection capability is required in the reservoir design per WAC 246-290-235(1)].
4. Installed high level and low level alarm system, with direct annunciation or notification to operations personnel.
5. Installed local level indication, either by a pressure gauge measured in "feet," or by an exterior site gauge.
6. Designed and installed drain facilities. (Section 9.6.2)
7. Designed and installed overflow pipe. (Section 9.6.3)
8. Tank atmospheric vents, with a non-corroding insect screen as described in Section 9.6.4.

9. Designed with locks on all hatches, access entries, sites fences, and access ladder extensions, to prevent unauthorized entry and vandalism.
10. Designed with water tight, insect proof access hatches, vents.[WAC 246-290-235(1)]
11. Access ways and ladders necessary to provide safe maintenance access.
12. Lightning arresters and electrical grounding, as applicable.
13. Removable silt-stop on the outlet pipe.
14. Leakage testing and disinfection per accepted standards, such as AWWA.
15. Slope of reservoir roof at a minimum of 2% (1/4" per foot).
16. Piping material below the reservoir and extending at least 10 feet from the perimeter of the structure constructed of sturdier materials as indicated in Section 9.6.6.
17. Separate inlet and outlet pipes to and from the reservoir to allow for effective turnover of the stored water. (These pipes should be on opposite sides of the reservoir and preferably at different elevations to prevent or minimize short-circuiting.)

9.6.2 Reservoir Drains

Reservoirs **must** be designed with drain facilities that drain to daylight or have an approved alternative that is adequate to protect against cross-connection contamination [WAC 246-290-235(1)]. The facilities should be capable of draining the full contents of the tank without entry to the distribution system, or causing erosion at the drainage outlet. Any connection to storm sewers or sanitary sewers is not recommended unless special circumstances or design features assure negligible risk of cross-connection contamination. The preferred method for cross connection protection would be the provision of a minimum two (2) pipe diameter air gap.

In locations where the topography is such that a drain to daylight is not feasible, the reservoir should be designed with a sump to allow for emptying the reservoir through use of a sump pump.

If an outlet pipe is also used as a reservoir drain, it should include a removable silt stop in the reservoir.

Drain lines may discharge directly to a dedicated dry well(s) provided precautions are designed and constructed to insure protection against backflow into the reservoir or distribution mains.

9.6.3 Reservoir Overflows

Reservoirs **must** be designed with an overflow pipe with atmospheric discharge or other suitable means to prevent a cross-connection [WAC 246-290-235(1)]. The overflow pipe should be designed to convey flow in excess of the design maximum supply rate to the reservoir. The overflow piping should also be designed such that overflow discharge will not cause erosion at the outlet. Any direct connection to storm drains or sanitary sewers is not recommended unless special circumstances or design features assure negligible risk of cross-connection contamination. A recommended method would be the provision of a minimum two (2) pipe diameter air gap at the outlet.

Overflow lines should have a non-corrodible mesh screen or mechanical device secured over its discharge end or, preferably, within the pipe to reduce susceptibility to damage by vandalism. If mesh is used, No. 24 non-corrodible mesh screening or equivalent is recommended.

9.6.4 Reservoir Atmospheric Vents

Reservoirs **must** have a screened roof vent per WAC 246-290-235(1). Overflows are not considered to be vents. To be effective, vents should be able to allow air into the reservoir at a rate greater than or equal to the rate that the water is withdrawn from the reservoir to prevent implosion or structural damage to the reservoir. The design should consider how to keep the vents from getting plugged or restricted and how to protect from frosting/freezing up or vandalism.

Upward facing vents **must not** be used in any application. Screens **must** be provided on the vents to prevent entry by birds or animals. For elevated tanks and standpipes, No. 4 mesh non-corrodible screen may be used. Ground level or underground reservoirs should terminate in an inverted “U” construction with the opening 24 to 36 inches above the roof or ground, and covered with No. 24 mesh non-corrodible screen. Screens on ground-level reservoir vents should be located within the pipe at a location minimally susceptible to vandalism.

9.6.5 Roof Drainage

The roof of the reservoir should be well drained. The slope of the reservoir roof should be a minimum of 2 % (1/4” vertical per foot horizontal). To avoid possible contamination, downspout pipes **must not** enter or pass through the reservoir (WAC 246-290-490).

9.6.6 Piping Material

Piping material used for pipelines constructed directly below the reservoir, and extending to at least 10 feet from the perimeter, should be sturdier material such as ductile iron pipe or AWWA C205 steel pipe with a corrosion resistant coating inside and out. Once the reservoir is in place, it is relatively difficult and expensive to repair or replace such pipe should it be broken or damaged due to differential settling or movement of the reservoir, or due to corrosion.

9.7 Operational Constraints and Considerations

All new reservoir designs are expected to meet all applicable OSHA and WISHA requirements. In addition, reservoir design and construction should consider the following issues:

1. Disposal of chlorinated water after construction and disinfection.

2. Disposal of tank drain line outflow and tank overflow stream.
3. Impacts to system operation if the new reservoir were to be taken off-line in the future for maintenance and/or cleaning.

9.7.1 Valving

Reservoir design **must** include a provision for tank isolation per WAC 246-290-235(1) in order to be able to perform maintenance. This may be accomplished by providing an isolation valve(s), which permit isolating the tank from the water system. An air release/vacuum relief valve should be installed on the distribution side of the isolation valve. A sample tap should be installed on the tank side of the isolation valve to allow for the required sample collection capability.

9.7.2 Tank Level Control

All new reservoirs should be equipped with a level control system designed to maintain reservoir water levels within a pre-set operating range (operating storage). As a minimum, the normal high and normal low water surface elevations that define this operating range should be specified in the design. A high level and low-level alarm system with direct annunciation of notification to operation personnel should be installed. There should also be a local level indication, either by a pressure gauge or by an exterior site gauge, measured by "feet."

Cable-supported float switches are inappropriate under conditions in which there is a potential for ice formation in the reservoir. Under these conditions, alternate means of tank level control and monitoring should be evaluated.

9.8 Reservoir Structural Design

Seismic risk **must** be taken into account when designing reservoirs (WAC 246-290-200). Refer to Chapter 13, Section 13.5.2 for additional guidance on seismic design of reservoirs.

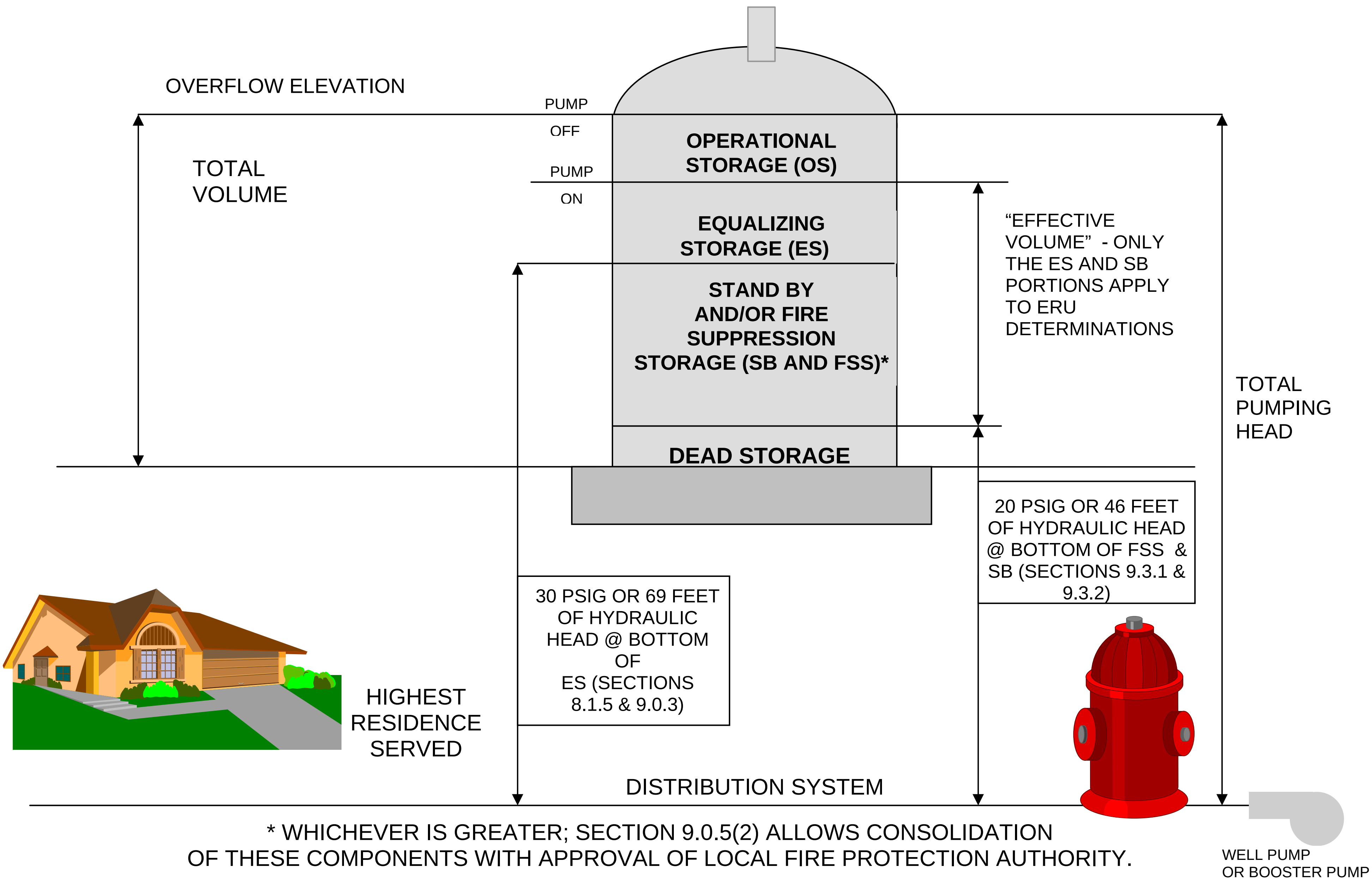
Table 9-1
Reservoir Storage Component Cross-Section Diagram

High Level Alarm. Overflow above ***pump off*** elevation

Pump Off All Pumps On	**Operational Storage (OS) Component** Not part of ES. Not applicable for continuous pumping systems. OS = Operational storage component (gallons).
Maintain 30 psi (Required)	**Equalizing Storage (ES) Component** For call-on-demand: ***ES = (PHD - Q_S)(150 min.),*** but in no case less than zero. *ES* = Equalizing storage component (gallons). *PHD* = Peak hourly demand (gpm). Q_S = Total of all permanent and seasonal sources (gpm). See Section 9.0.3 for sizing criteria for continuous pumping operations.
Low Level Alarm Maintain 20 psi (Required)	**Fire Suppression Storage (FSS) Component** For Single Sources and Multiple Sources: ***FSS = (FF)(t_m)*** FSS = Fire suppression storage component (gallons). FF = Needed Fire Flow rate, expressed in gpm as specified by fire authority or the Coordination Act, whichever is greater. t_m = Duration of FF rate, expressed in minutes as specified by fire authority or the Coordination Act, whichever is greater.
Maintain 20 psi (Recommended)	**Standby Storage (SB) Component** For Single Sources: ***SB_{TSS} = (2 days) (ADD)(N)*** For Multiple Sources: ***SB_{TMS} = (2 days)(ADD)(N) - t_m(Q_s-Q_L)*** *SB* = Standby storage component per local community expectations (gallons). *TSS, TMS* = Total for systems with a single source and multiple sources, respectively. *ADD* = Average daily demand for the design year (gpd/ERU). Q_S = The sum of the all source of supply capacities continuously available to the system (gpm). Q_L = The installed capacity of the largest source (gpm). *N* = Number of ERUs. t_m = Time that remaining sources are pumped when the largest source is not available (minutes). A minimum SB volume sufficient to provide at least 200 gallons per ERU is recommended.
	Dead Storage (DS) Portion of a gravity reservoir that does not provide required minimum pressure.

FIGURE 9-1

RESERVOIR STORAGE COMPONENTS



* WHICHEVER IS GREATER; SECTION 9.0.5(2) ALLOWS CONSOLIDATION OF THESE COMPONENTS WITH APPROVAL OF LOCAL FIRE PROTECTION AUTHORITY.